International Journal of Electrical and
Electronics Engineering Research (IJEEER)
ISSN(P): 2250-155X; ISSN(E): 2278-943X
Vol. 4, Issue 1, Feb 2014, 197-202

EFFECT OF VARYING VOLTAGE REFERENCE OF SVC FOR STEADY STATE OPERATING CONDITIONS

RITESH ROBIN STANLEY[1] & SANTOSH KUMAR M H[2]

[1]Engineer, PRDC Pvt. Ltd, Bangalore, Karnataka, India

[2]Research Scholar, BEC, Bagalkot, Karnataka, India

ABSTRACT

With increasing complexity of the network and the rising demand, the need for maintaining the operational parameters of the power system within limits increases. Normally it is preferred to have reactive power compensation done locally at the load points or at low voltage pockets in the system to improve the voltage profile. With improving technology and the introduction of Flexible AC Transmission Systems (FACTS) devices, reactive power compensation of the network is done with better controllability. The major disadvantage associated with FACTS devices is the cost. In this paper, it has been shown through simulation studies that, if the maximum deviations in loads are known, based on these loading conditions a Static VAr Compensator (SVC) rating can be used for reactive power compensation by varying the voltage reference to gain better voltage profile. It has also been concluded that for future load growth, instead of considering new compensation devices varying the voltage reference of the existing SVC would be sufficient to bring the voltages within the acceptable operation limits thereby differing investments.

KEYWORDS: Flexible AC Transmission System (FACTS), Load Flow Studies, Reactive Power Compensation, Simulation, Static VAr Compensator (SVC), System Losses and Voltage Profile

INTRODUCTION

Reactive power compensation is an important aspect of power system operation and planning. During power system planning studies, it is ensured that large amounts of reactive power are not transmitted and compensation for loads is done at the load tapping point itself [1]. Reactive power is also required to maintain the voltage within the operational limits. If not it becomes a power quality issue. To avoid such issues generally low/high voltage pockets and load points in the network are considered as potential points for reactive power compensation.

The nature of compensation devices to be employed such as a shunt capacitor or shunt reactor will depend on the operating voltage and the loading condition. Depending on the nature of the system and the operating loading condition, the voltage can vary above and below the prescribed voltage limits. For such systems it is advantageous to have proper control over the reactive power being generated. This control has been largely achieved through the usage of Flexible AC Transmission Systems (FACTS) such as SVC, Static Compensator (STATCOM), Unified Power Flow Controller (UPFC) etc. There are many other advantages that can be realized through FACTS devices like Power Oscillation Damping (POD), improving power transferred in transmission lines and improve stability margins of the power system [2].

This paper discusses about the SVC characteristics and the possible advantages envisioned by varying voltage reference of SVC which is discussed through simulation results. The results are discussed by simulating IEEE 9 bus test system using Mi Power power system simulation package.

STATIC VAR COMPENSATOR (SVC)

SVC is a shunt FACTS device, used extensively for reactive power compensation purposes. SVC has also been used for power oscillation damping, flicker eliminations in arc furnaces, balancing load in individual phases, to reduce temporary overvoltage, to damp sub synchronous oscillations and improving transient stability margins of the network [3]. SVC are basically made of few controllable and / or switched elements as shown in figure 1 [3, 4] such as,

- Thyristor Controlled Reactor (TCR)
- Thyristor Switched Capacitor (TSC)
- Fixed Capacitor (FC)
- Mechanically Switched Capacitor (MSC)
- Thyristor Switched Reactor (TSR)
- Saturated Reactor Compensator

Generally capacitor cannot be controlled due to integration of current. Control of reactive power is achieved by varying the reactor. This phenomenon is achieved by variation of the thyristor firing angle. But by varying thyristor angle, the symmetry of the waveform is lost leading to the production of harmonics. This has lead to designing of filters as part of SVC itself which is achieved by converting few fixed capacitors as tuned or damped filter or both based on the harmonic distortion levels. SVCs' are generally controllable within the control range, beyond which the SVC will be purely capacitive or inductive in nature.

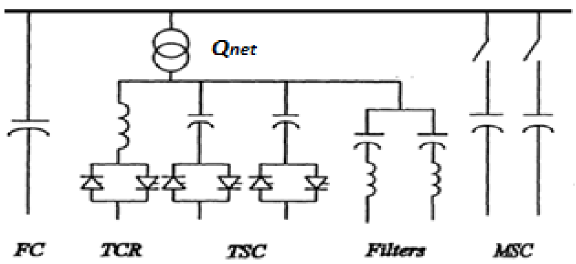

Figure 1: Different Elements that Constitute an SVC

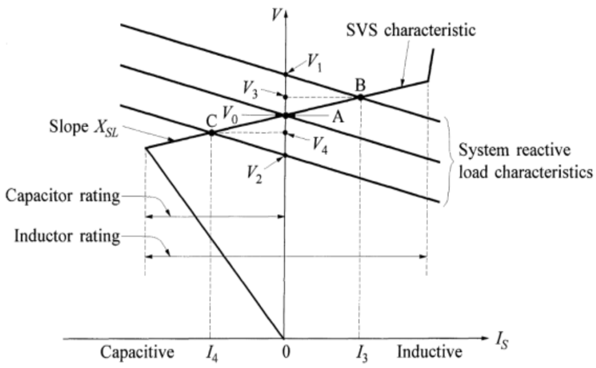

Figure 2: Sample SVC Characteristics

Figure 2 gives a sample SVC characteristic [5]. The characteristics can be divided into 3 operational regions based on the sample characteristics. Between origin and ΔV_{cmax}, the characteristics are completely capacitive with no influence of inductance. The actual SVC control region is between ΔV_{Cmax} and ΔV_{Lmax}. In this region the TCR present starts to operate and at ΔV_{Lmax} the firing angle is zero degree. Beyond ΔV_{Lmax} point, enters an inductive region.

TEST SYSTEM AND ANALYSIS

The effect of voltage reference variation of SVC is studied using IEEE 9 bus test system for steady state operations. Mi Power simulation package [6] is used for performing the analysis. The single line diagram is shown in figure 3 and the network data [7, 8] is presented in appendix 1.

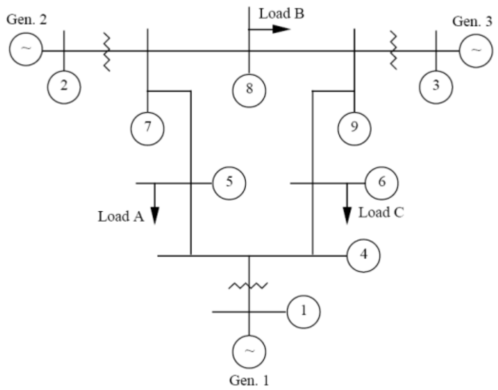

Figure 3: IEEE 9 Bus Test System

The system analysis was carried with parameters on 100 MVA base. Fast decoupled type of load flow method was used for analyzing the steady state condition of the network. Base case is considered as the system without SVC. After base case load flow simulation, SVC was considered at bus 9 as all the buses had voltage greater than 1 pu and bus 9 had the highest voltage in the network above the nominal 1 pu value. Generator buses are not considered for compensation. Important results of analysis are presented in the observation section.

For proper designing of SVC, generally load variation information and the operational voltage limits should be known. Since operational voltage limits details are not known, it is considered to bring the voltage profile as close to 1 pu as possible. The base case is taken as minimum loading case causing over-voltages. The SVC details considered were 10 MVAr fixed capacitor at 1 pu voltage and 50 MVAr extended into the inductive region (combined reactance and capacitance rating) and was connected at bus 9. The slope was calculated at 1 pu reference and 0.99 pu V_{cmax} voltages which is given by the equation,

$$Slope = {}^{\Delta V_{cmax}}/_{I_{cmax}} \tag{1}$$

From the given details slope was computed as 0.11 pu on common MVA base. With the same slope in place, the voltage reference was varied in steps of 0.01 pu and load flow analysis was executed for each step. The effect on the voltage profile at the point of connection of the SVC was noted.

THEORY OF VARYING VOLTAGE REFERENCE

SVC is a device which does not bring the system operating voltage at the point of connection to the nominal voltage value. Instead SVC tries to improve voltage as much as possible closer to the nominal value and it largely depends on the slope value. The diagrammatical explanation of the effect of voltage variation is shown in figure 4. Figure 4 deals with a case where the system voltage lower than the nominal value and has scope for voltage improvement. The SVC is considered to be having the same slope for all the cases.

From equation 1 slope of SVC can be computed. The control range in the SVC characteristics is represented between VCmax and VLmax. The system voltage without SVC is the point in the graph where system characteristics meet

the Y-axis. The point where the system characteristics meet the control range of SVC is the new system operational point. The corresponding Y-axis value will be the new voltage level after addition of SVC. If the same slope is maintained and the control range is shifted slightly based on the network operation (for under voltage system shift control range curve above and for over voltage system shift control range curve down), the system operational meeting point with the SVC characteristics changes thereby altering the voltage value also. The control range curve is shifted by varying the voltage reference point and the VCmax and VLmax by the same voltage step, thereby maintaining a constant slope value. The voltage level will improve further if control curve is shifted above and will reduce when control curve is shifted down.

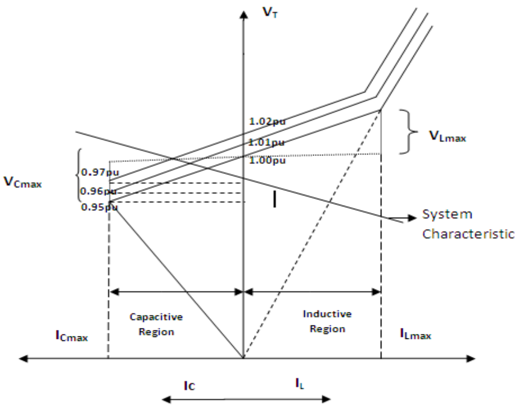

Figure 4: SVC Characteristics with Varying Voltage Reference

OBSERVATIONS

With the same rating of SVC and by varying voltage reference, the voltage at bus 9 is tabulated in table 1. The variation in voltage reference brought about better improvement in voltage profile. Voltage can be brought within limits if there exists overvoltage in the network by reducing the voltage reference. Similarly, if voltage has to be improved voltage reference should be increased. More detailed study needs to be carried out to ascertain the extent of possible variation in voltage reference value for a given SVC.

Table 1: Results of Load Flow Studies for Varying Voltage Reference

Cases	Voltage Reference (pu)	Bus 9 Voltages / Point of SVC Connection (pu)
Base case	No SVC	1.0305
1	1.00	1.0226
2	0.99	1.0199
3	0.98	1.0173
4	0.97	1.0143
5	0.96	1.0117
6	0.95	1.0106

CONCLUSIONS

The conclusions presented are strictly with respect to the case studies carried out for analysis and the projected future scope of work.

- When there is under voltage in the system, voltage can be improved by increasing the voltage reference and vice versa.
- Considering continuous growth in load over the years, it is possible to maintain voltage profile within operational limits provided SVC voltage reference is varied instead of installing new compensation devices. Sometimes it

might lead to installing smaller rating compensation devices for managing the load growth. This might lead to eliminating additional investments.

- The variation of voltage reference cannot be done beyond specific limits considering inductance saturation and rating of the components.
- The effect of dynamically varying voltage reference on the system has to be studied through transient programs to get a better understanding on the stability of the system as the studies presented here are only for steady state conditions.

ACKNOWLEDGEMENTS

Authors place on record the colleagues and friends at PRDC Pvt. Ltd., Bangalore and the professors and lecturers at BEC, Bagalkot for their endless support and help.

REFERENCES

1. *Manual on transmission planning criteria*. Gov. of India, Ministry of Power, CEA, New Delhi - 2013
2. Narain G. Hingorani and Laszlo Gyugyi, "*Understanding FACTS: Concepts and Technology of Flexible AC Transmission System"*, IEEE press, John Wiley & Sons Inc. publications, 1999
3. *Static VAr Compensator.* CIGRE WG 38-01, Task Force No.2 on SVC, 1986
4. M. Noroozian, "*SVC Modeling in Power Systems"*, Information NR 500-026E, April 1996
5. Prabhakundur, "*Power System Stability and Control"*, EPRI, Tata McGraw-Hill publications, ninth reprint 2010, pp. 639 - 678
6. MiPower™ Software, http://www.prdcinfotech.com/products.html
7. Rajeev Kumar Ranjan, *Parametric Approach to Steady-State Stability Analysis of Power Systems*, M.S Thesis under guidance of M. A. Pai, University of Illinois, Urbana, 1992
8. Swaroop Kumar, Nallagalva, Mukesh Kumar Kirar and Dr. Ganga Agnihotri, *Transient Stability Analysis of IEEE – 9 bus Electric Power System*, International Journal of Scientific Engineering and Technology, vol No.1, Issue No. 3, pg: 161-166, 01 July 2012

APPENDICES

Transmission Line and Transformer Data on 100 MVA Base

Table 2

From Bus	To Bus	Resistance in pu	Reactance in pu	Susceptance in pu
1	4	0.0000	0.0576	0.0000
4	6	0.0170	0.0920	0.1580
6	9	0.0390	0.1700	0.3580
9	3	0.0000	0.0586	0.0000
9	8	0.0119	0.1008	0.2090
8	7	0.0085	0.0720	0.1490
7	2	0.0000	0.0625	0.0000
7	5	0.0320	0.1610	0.3060
5	4	0.0100	0.0850	0.1760

Bus Data of IEEE 9 Bus System. All per Unit Values on 100 MVA Base

Table 3

Bus No	Bus Type	Generation (pu)		Load (pu)		Voltage Magnitude (pu)
		P_G	Q_G	P_L	Q_L	
1	Swing	-	-	-	-	1.040
2	PV	1.63	-	-	-	1.0253
3	PV	0.85	-	-	-	1.0253
4	PV	-	-	-	-	-
5	PQ	-	-	1.25	0.50	-
6	PQ	-	-	0.90	0.30	-
7	PQ	-	-	-	-	-
8	PQ	-	-	1.00	0.35	-
9	PQ	-	-	-	-	-